Backreaction of heavy fields in string-effective inflation models

Clemens Wieck, Deutsches Elektronen-Synchrotron DESY

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Outline

1. Inflation in supergravity and stabilizer fields
2. Non-perturbative moduli stabilization
3. Backreaction of heavy fields
4. Examples in Starobinsky-like inflation
5. Conclusions

1. Inflation in supergravity and stabilizer fields

Inflation?

- Why is the universe as flat as it is?
- How can the Cosmic Microwave Background (CMB) radiation be so isotropic?
- And where are all those magnetic monopoles?

$\hookrightarrow$ Cosmic inflation, exponential expansion of space

[Guth '81]
[Linde '82]

Inflation in supergravity

- Single-field inflation in supergravity described by

$$S = \int \mathrm{d}^4x \sqrt{-g} \left(\frac{1}{2} R - \frac{1}{2} \partial_\mu \varphi \partial^\mu \varphi - V(\varphi) \right)$$

- Impose slow-roll conditions

$$\epsilon = \frac{1}{2} \left(\frac{V'}{V} \right)^2 \ll 1 \,, \qquad \eta = \left| \frac{V''}{V} \right| \ll 1 \,.$$

CMB observables

- Observations useful to constrain supergravity models

- Measure two central quantities,

- ratio of tensor-to-scalar fluctuations r

- spectral index of scalar fluctuations n_s

$\hookrightarrow$ Planck: $n_s \approx 0.96$, $r < 0.1$

BICEP2: $r \approx 0.16$ dust?

Joint analysis: $r \sim 0.05$?

Inflation in supergravity

- However, supergravity scalar potential usually too steep,

$$V = e^{K}\left(K^{I\bar{J}}D_IW\overline{D_JW} - 3|W|^2\right)$$

- Possible solutions:

  1. Shift symmetry

     $\hookrightarrow$ e.g. axions in string theory

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  2. No-scale symmetry

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1. Shift symmetry
   $\hookrightarrow$ e.g. axions in string theory
2. No-scale symmetry
   $\hookrightarrow$ generic in string theory
3. Stabilizer fields
   $\hookrightarrow$ stringy origin less obvious

Chaotic inflation with "stabilizer field"

- Introduce additional chiral multiplet to make potential stable and bounded from below,

[Kawasaki et al. '00]
[Kallosh et al. '10]

$$W = MSf(\Phi)\,, \qquad K = \frac{1}{2}(\Phi + \overline{\Phi})^2 + |S|^2\,.$$

Inflation with "stabilizer field"

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$$W = M S f(\Phi)\,, \qquad K = \frac{1}{2}(\Phi + \overline{\Phi})^2 + |S|^2\,.$$

- Inflaton potential, with $\langle S \rangle = 0$ and $\langle \mathrm{Re}\,\Phi \rangle = 0$ stabilized,

$$V = |M f(\mathrm{Im}\,\Phi)|^2$$

$\hookrightarrow$ well-suited for single-field slow-roll inflation

2. Non-perturbative moduli stabilization

Moduli stabilization (in type IIB)

- In 4D, all moduli flat directions at perturbative string tree-level
- First, fix complex structure (and dilaton) with RR and NS-NS flux

[Giddings et al. '02]

- Then, stabilize Kahler moduli using non-perturbative corrections to superpotential, e.g.,

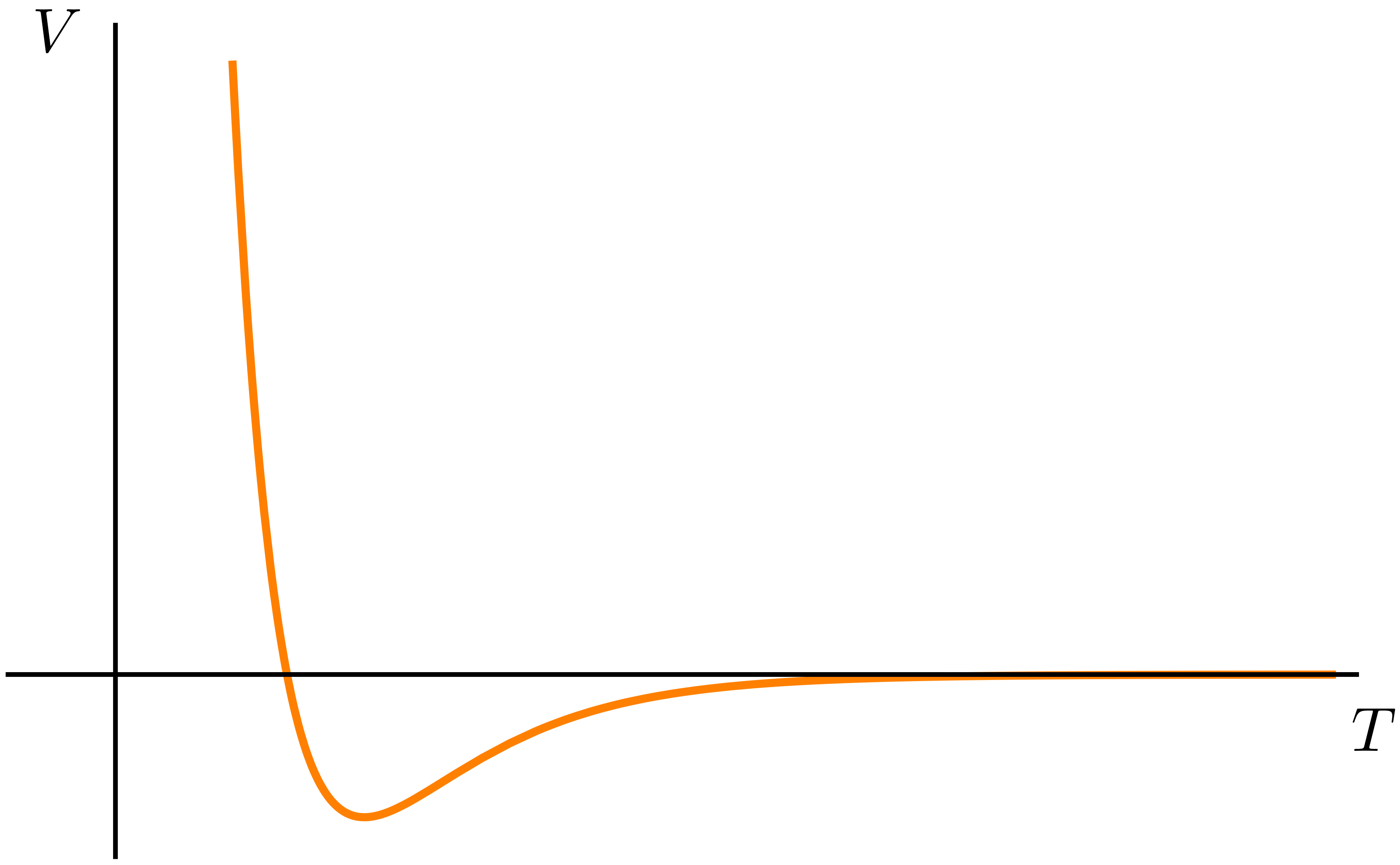
[Kachru et al. '03]

$$W = W_0 + Ae^{-aT}\,, \qquad K = -3\ln\left(T + \overline{T}\right)$$

Here, W_0 and A fixed by fluxes, a dependent on origin of non-perturbative term

Moduli stabilization

- KKLT: Solving $D_T W = 0$ gives a supersymmetric AdS vacuum

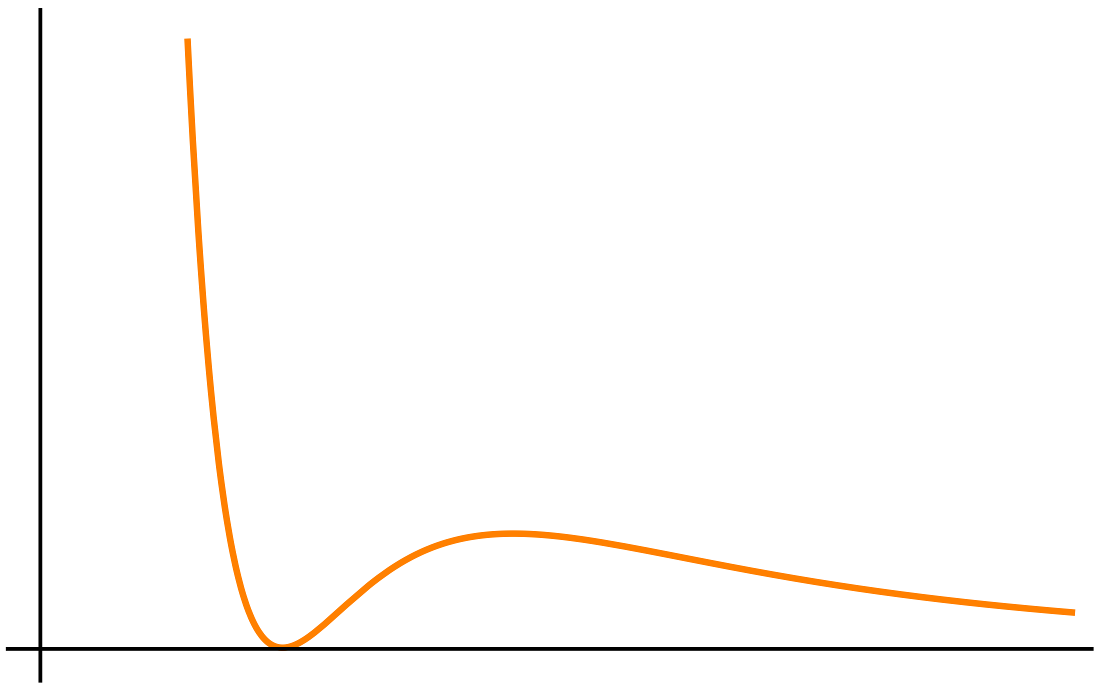


Uplift to Minkowski vacuum

- Then: uplift to non-supersymmetric Minkowski or near-dS vacuum via F-terms or D-terms, e.g., Polonyi field

$$W_{\mathsf{up}} = fX\,, \qquad K_{\mathsf{up}} = |X|^2 + \ldots$$

- To cancel cosmological constant, choose $f \approx \sqrt{3}W_0$. Then,



Caveats in KKLT

(and related mechanisms)

- Drawback: flux quanta generically give $W_0 \sim O(1)$

  $\hookrightarrow$ To obtain TeV-scale gravitino mass, fine-tune W_0

- However: when coupled to inflation, require

$$m_{3/2} > H_{\mathsf{inf}}$$

for modulus to remain stabilized

[Kallosh, Linde '04]

3. Backreaction of heavy fields

Backreaction of stabilizer fields

- Once coupled to supersymmetry breaking, stabilizer field mixes with the inflaton, not stabilized at origin any longer,

$$W = MSf(\Phi) + W_{\cancel{\text{SUSY}}}$$

$$\Rightarrow V_{\text{soft}} \sim m_{3/2}\left[\operatorname{Re} S f_1(\varphi) + \operatorname{Im} S f_2(\varphi)\right]$$

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- Integrate out S and find corrected effective inflaton potential,

$$V(\varphi) = |Mf(\varphi)|^2 - m_{3/2}^2 \frac{f_1^2(\varphi) + f_2^2(\varphi)}{M_S^2}$$

$\hookrightarrow$ backreaction destructive for some threshold value of $m_{3/2}$

Backreaction of heavy moduli

- Procedure similar: coupling induces inflaton-dependence of modulus vacuum, integrate out to compute backreaction

$$W = W_{\mathsf{inf}}(\Phi) + W_{\mathsf{mod}}(T_\alpha)\,, \qquad K = K_0(T_\alpha, \overline{T}_{\bar{\alpha}}) + \frac{1}{2}(\Phi + \overline{\Phi})^2 K_1$$

[Buchmüller et al. '14, Buchmüller et al. '15]
[Dudas et al. '15]

- If moduli break supersymmetry, backreaction reintroduces dangerous $-3|W|^2$ term and other non-decoupling effects

4. Examples in Starobinsky-like inflation

Starobinsky with a stabilizer field

$$K = -2\log\left(\Phi + \overline{\Phi}\right) + k_1(|S|^2)$$

$$W = MS\underbrace{(\Phi - \Phi^2)}_{f(\Phi)}$$

Starobinsky with a stabilizer field

$$K = -2\log(\Phi + \overline{\Phi}) + k_1(|S|^2)$$

$$W = MS(\underbrace{\Phi - \Phi^2}_{f(\Phi)})$$

$$\Rightarrow V_{\mathsf{inf}} \sim M^2(1 - e^{-\varphi})^2$$

$\hookrightarrow$ exponentially flat plateau for canonically normalized inflaton

Starobinsky with a stabilizer field

$$K = -2\log\left(\Phi + \overline{\Phi}\right) + k_1(|S|^2) + k_2(|X|^2)$$

$$W = MS(\Phi - \Phi^2) + \underbrace{fX}_{\text{Polonyi field}} + W_0$$

Starobinsky with a stabilizer field

$$K = -2\log(\Phi + \overline{\Phi}) + k_1(|S|^2) + k_2(|X|^2)$$

$$W = MS(\Phi - \Phi^2) \overbrace{+ fX + W_0}$$

Polonyi field

$$\Rightarrow V(\varphi) = V_{\mathsf{inf}}(\varphi) - \frac{M^2 W_0^2 (2 - e^{\varphi})^2}{M_S^2}$$

$\hookrightarrow$ backreaction destroys plateau for large W_0 and large φ

$\Rightarrow 50 - 60$ e-folds impossible when $m_{3/2} \gtrsim 10^{10}$ GeV

Starobinsky with a stabilizer field

- Implication: model incompatible with moduli stabilization a la KKLT, LVS, ...

- Similar results for many other string-effective Starobinsky-like models, Cecotti model, Goncharov-Linde model, ...

$\hookrightarrow$ next: try no-scale symmetry

Starobinsky in no-scale supergravity

$$K = -3\log\left(T + \overline{T} - \tfrac{1}{3}|\Phi^2|\right),$$

$$W = M(\Phi^2 + b\Phi^3)$$

[Ellis et al. '13, '14, '15]

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- Fine-tune b, assume T stabilized at some $T_0 \gg 1$

$$V_{\mathsf{inf}}(\varphi) \sim M^2(1 - e^{-\varphi})^2$$

- How can T be stabilized consistently?

Starobinsky in no-scale supergravity

$$K = -3\log\left(T + \overline{T} - \tfrac{1}{3}|\Phi^2|\right),$$

$$W = M(\Phi^2 + b\Phi^3) + W_{\mathsf{mod}}(T)$$

Starobinsky in no-scale supergravity

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- Backreaction of T sources steep terms which make inflation impossible

$$\ldots \quad V(\varphi) \sim V_{\mathsf{inf}}(\varphi) + M m_{3/2}\sinh^2\varphi - M^2\sinh^4\frac{\varphi}{2} + \ldots$$

soft term, if T breaks supersymmetry

from $-3|W|^2$, generic

5. Conclusions

Conclusions

- Backreaction of heavy fields on inflation important even for $M \gg H$ if supersymmetry is broken

  $\hookrightarrow$ generic concern in most string-effective models

- Stabilizer fields do not like high-scale supersymmetry

- Starobinsky-like models particularly constrained by stabilizer field or stabilized moduli

- Natural inflation generically less constrained due to periodicity of potential & backreaction terms